Completion of ArgoNeuT NuMI Run

All Experimenter's Meeting

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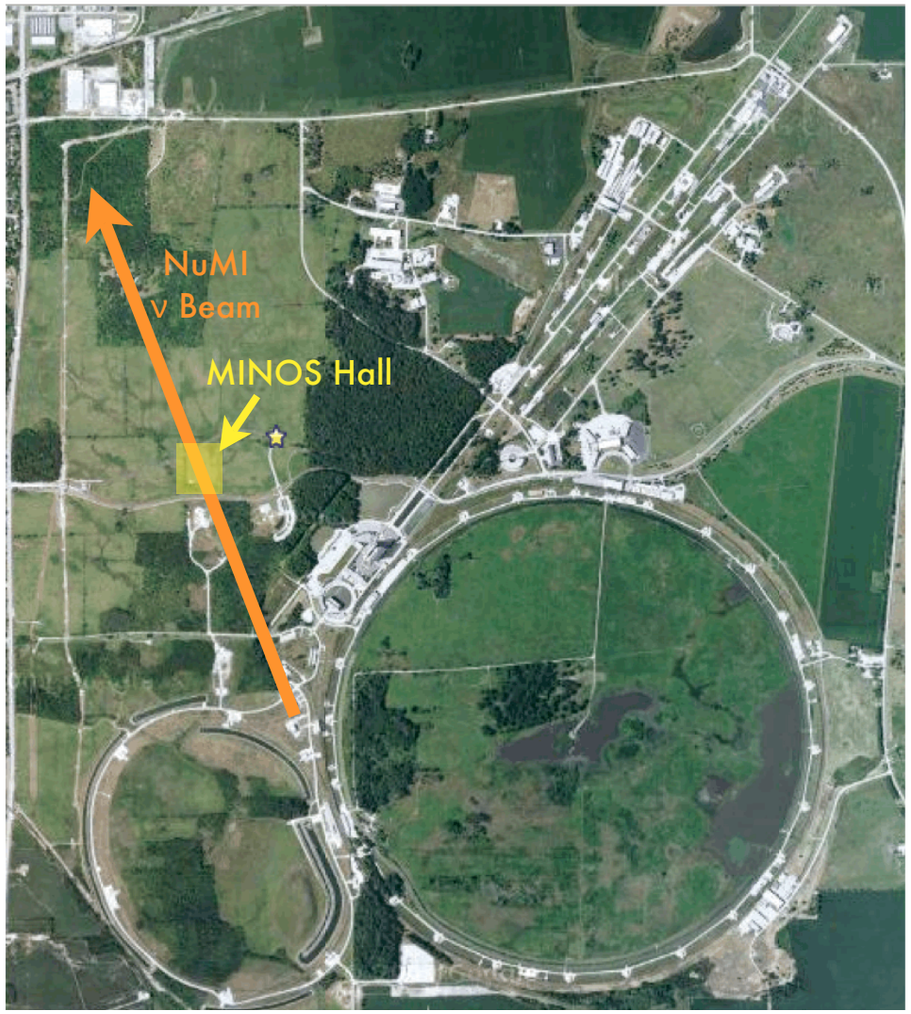
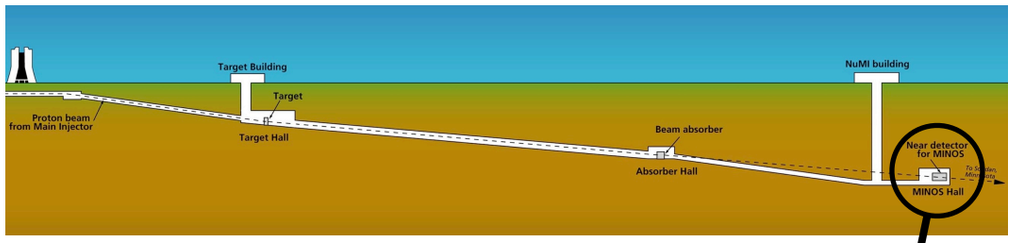
3/15/2010

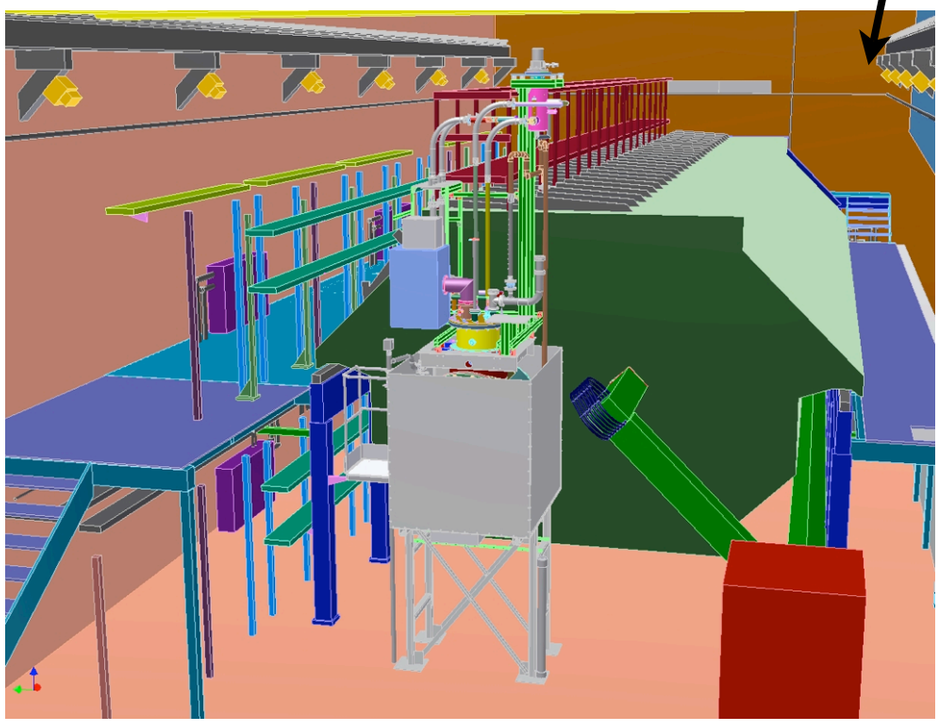
ArgoNeuT

- ArgoNeuT is a ~175 liter Liquid Argon Time Projection Chamber (LArTPC) neutrino detector.
- Jointly funded by DOE/NSF
- Ran in NuMI beam at Fermilab, in front of MINOS near detector (to aid in muon reconstruction).
- Goals:
  - Gain experience building/running LArTPCs.
  - Accumulate neutrino/antineutrino events (1st time in the U.S., 1st time ever in a low-E beam).
  - Develop simulation/reconstruction for LArTPCs and compare with data.



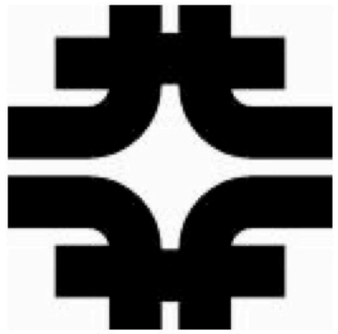
Fermilab





MINOS Hall at Fermilab

ArgoNeuT: Collaboration



6 Institutions,
20 collaborators

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University of L'Aquila

B. Baller, C. James, G. Rameika, B. Rebel
Fermi National Accelerator Laboratory

M. Antonello, R. Dimaggio, O. Palamara
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C. Bromberg, D. Edmunds, P. Laurens, B. Page
Michigan State University

S. Kopp, K. Lang
The University of Texas at Austin

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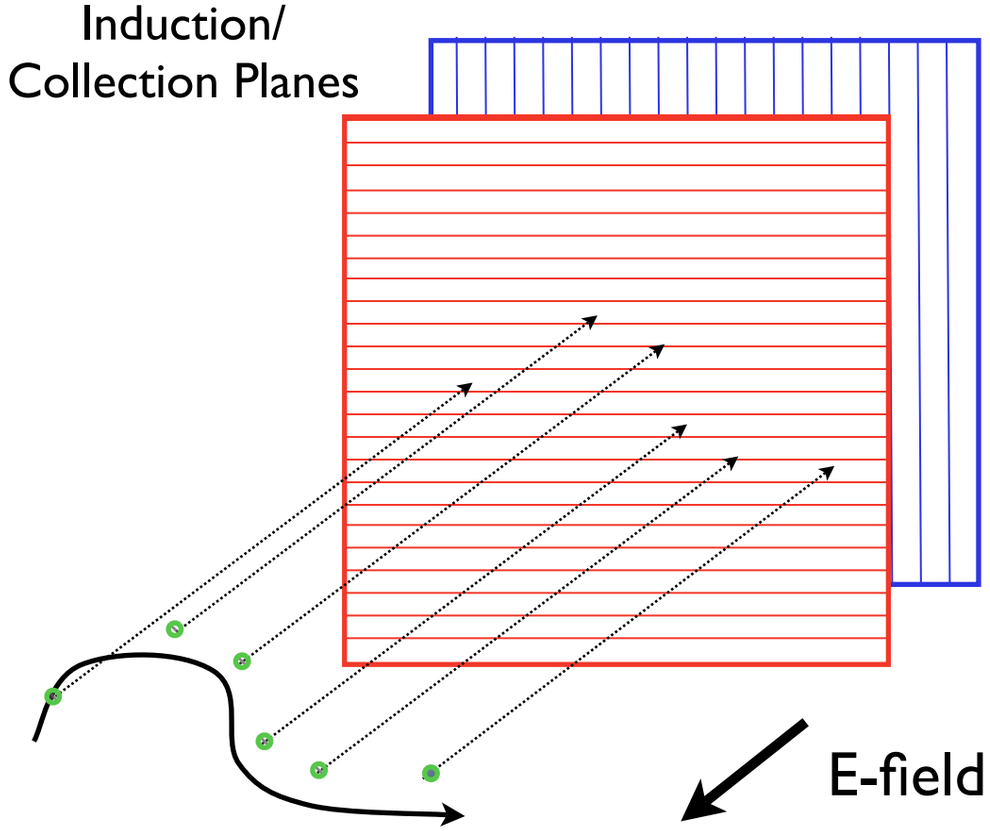
Yale University

* = *Spokesperson*

LArTPC Principle: Reminder

TPC = Time Projection Chamber

- Neutrino interactions inside a TPC produce particles that ionize the argon as they travel (55k e^-/cm).
- Ionization is drifted along E-field to wireplanes, consisting of wires spaced a few mm apart.
- Location of wires within a plane provides position measurements...multiple planes give independent views.
- Timing of wire pulse information is combined with drift speed to determine drift-direction coordinate.
- Scintillation light also present, can be collected by Photomultiplier Tubes and used in triggering.



Refs:
1.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

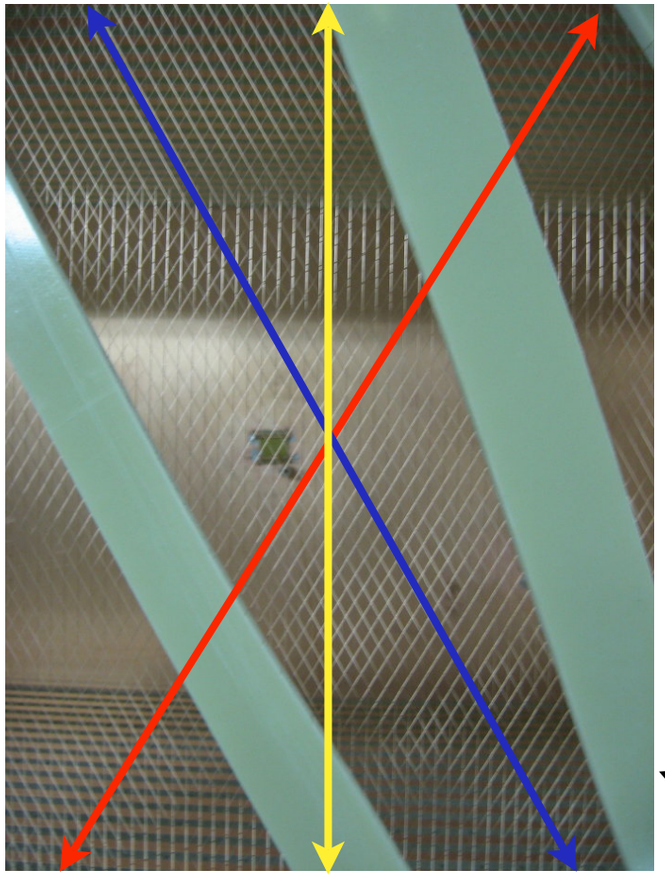
ArgoNeuT: TPC

Cryostat Volume	~500 Liters
TPC Volume	175 Liters
# Electronic Channels	480
Wire Pitch	4 mm
Plane Separation	4 mm
Electric Field	500V/cm
Max. Drift Time	330μs
Wire Properties	0.15mm diameter BeCu

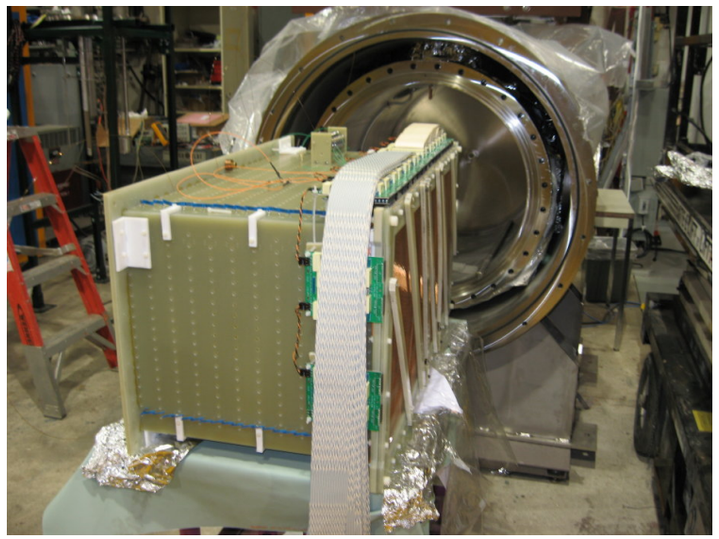
Collection Induction #1 Induction #2

±60° wires

ν beam



Wire Orientations

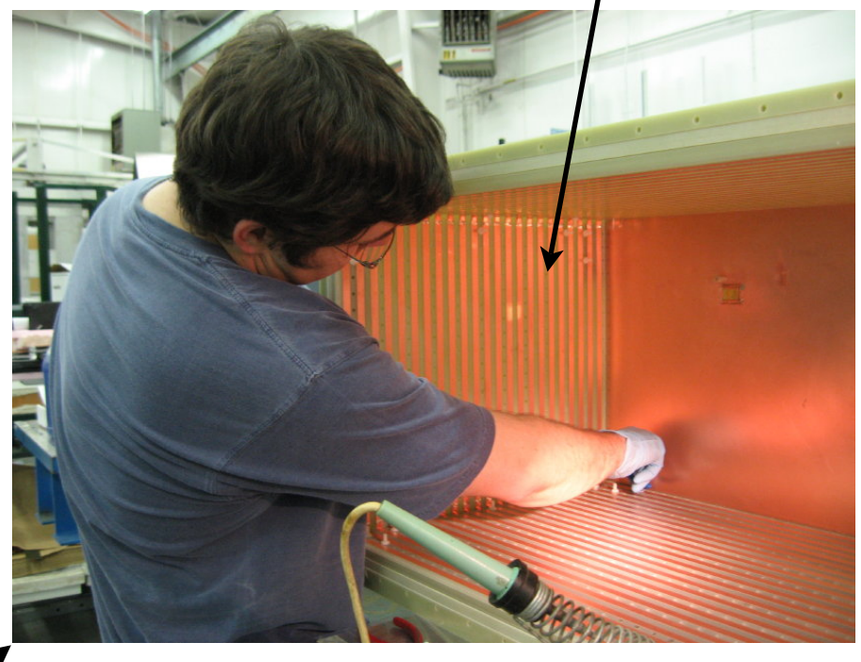


TPC About to Enter Cryostat (at PAB)

Used winding machines at Lab 6

Used routing machines at Lab 8

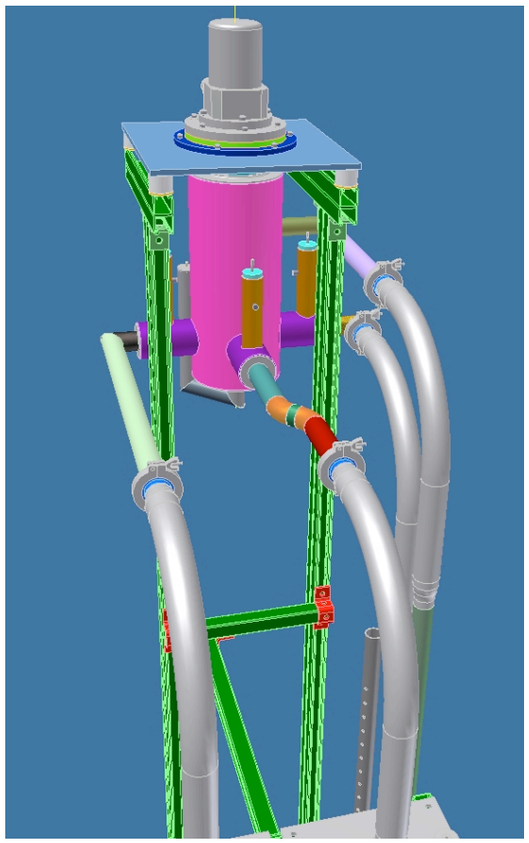
Electric Field Rings



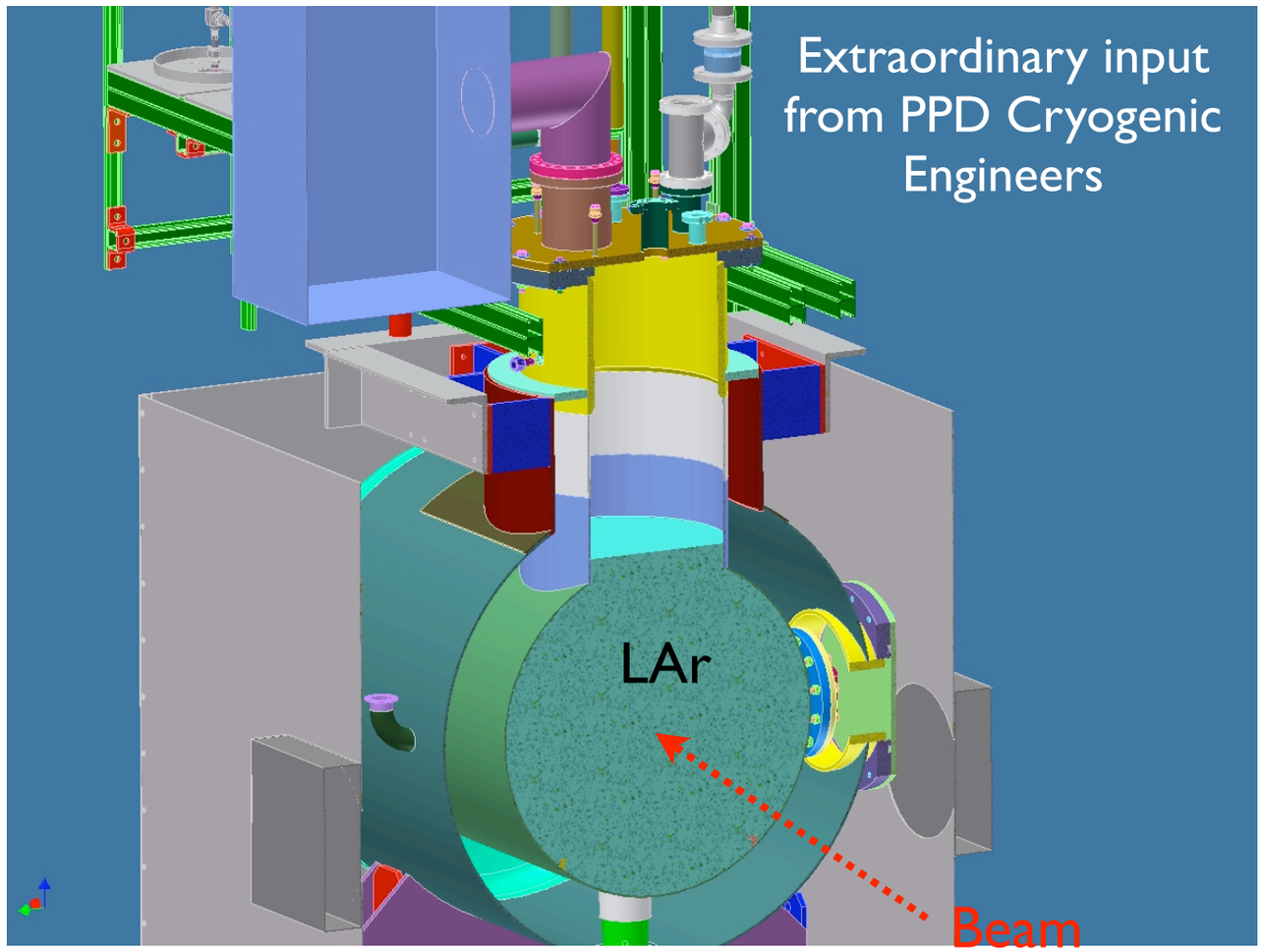
TPC Field Cage formed out of copper-clad G10 boards

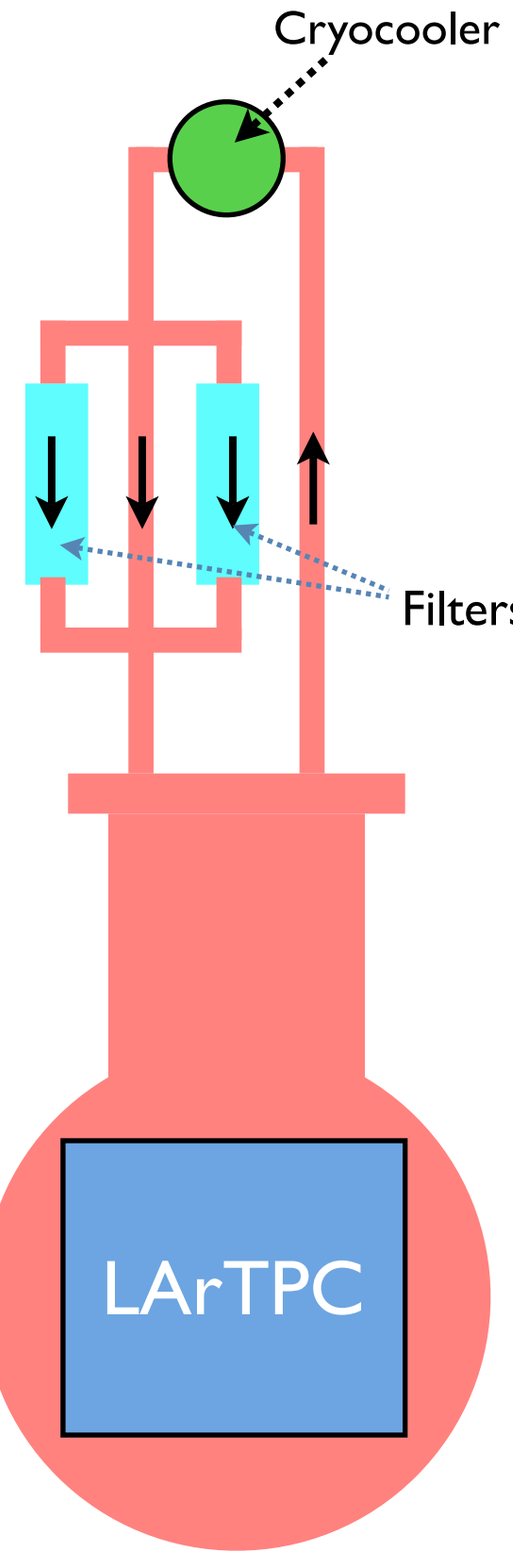
ArgoNeuT: Cryogenics

- Self-contained system....no refills.
- Continuously circulate argon through filters to purify.
- Cryocooler utilized to condense boil-off gas.
- Vacuum jacketed cryostat has 550 liter capacity.
- System designed to maintain ODH-0 rating of NuMI tunnel.



300W Cryocooler

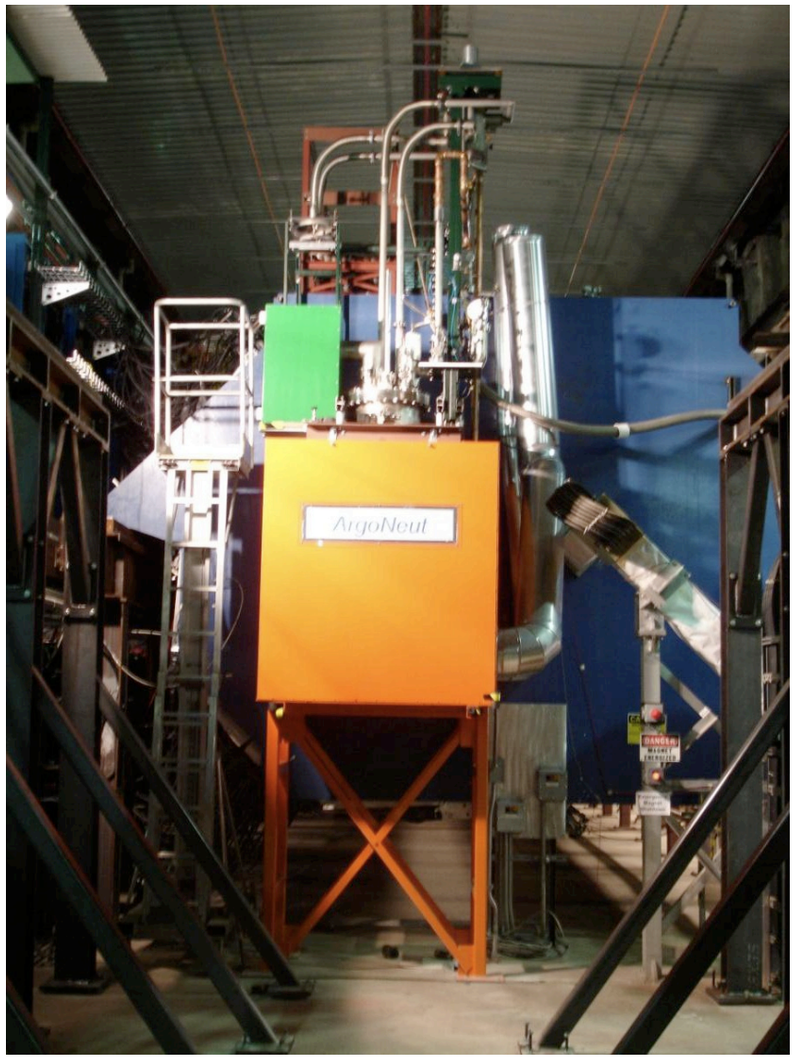




ArgoNeuT: NuMI Run

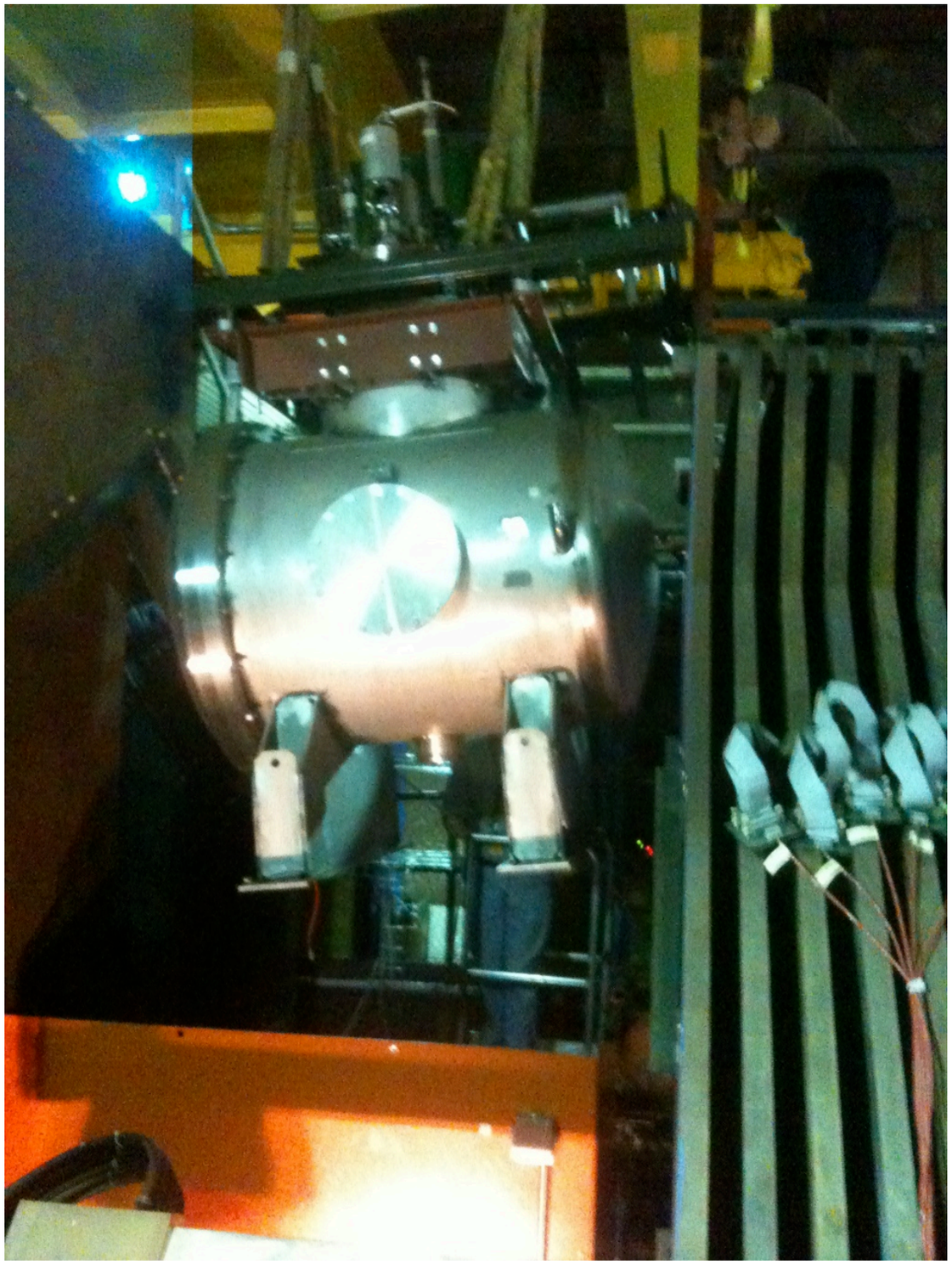
- Filled the detector underground for the first time on Friday, May 8, 2009
- Acquired neutrino data for ~1 month before summer 2009 shutdown...continued running in the Fall, mostly in antineutrino mode
- Cryo. system operated continuously since initial fill, (modulo cryocooler repair for ~2 weeks in October).
- Run ended on Feb. 22, 2010, and system is now completely removed from the tunnel.

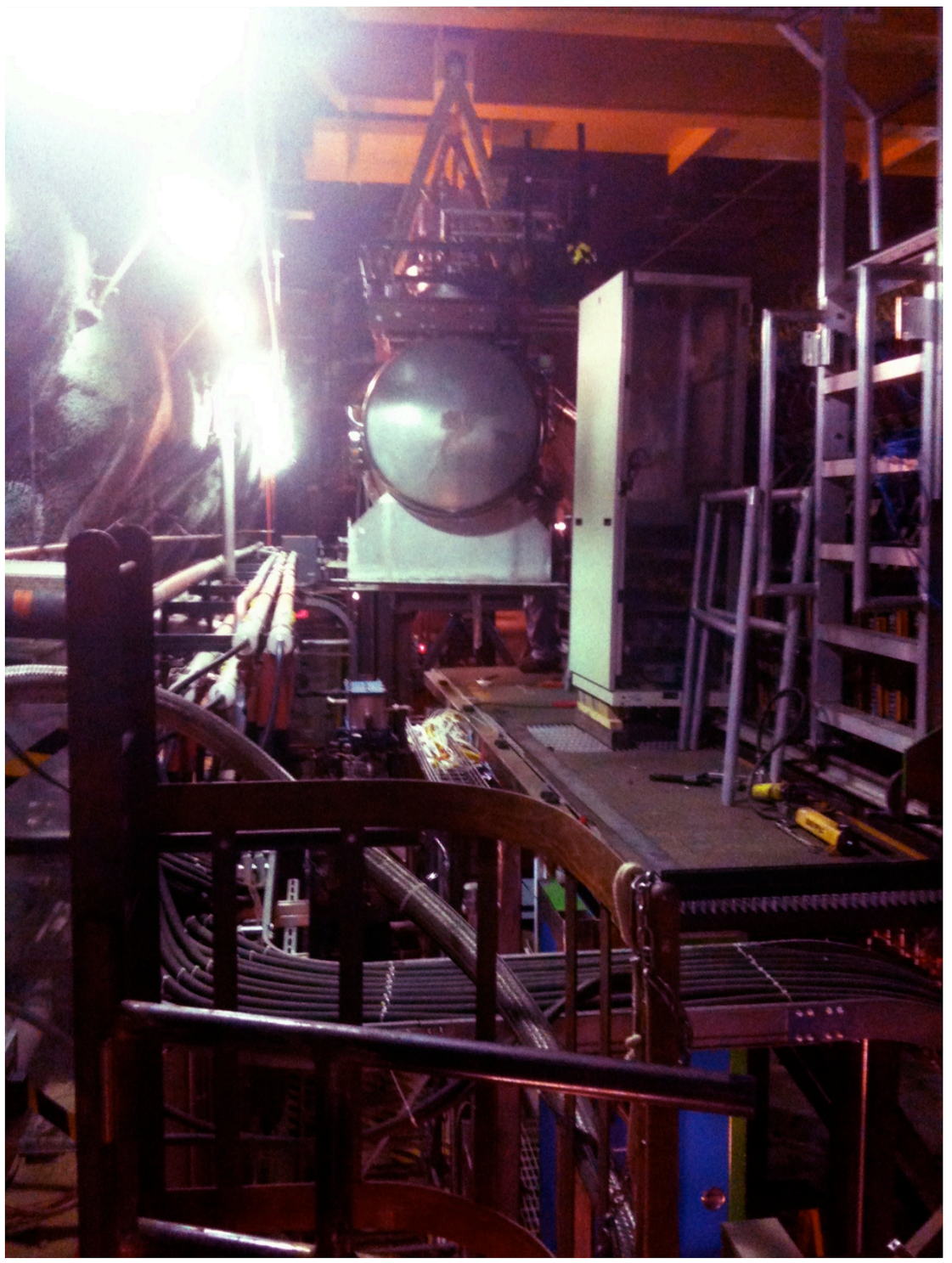
Moving underground
(lowering down 350 ft. shaft)



Installing underground.

ArgoNeuT: Removal





Safe and expedient process thanks to John Voirin and crew

ArgoNeuT: Removal

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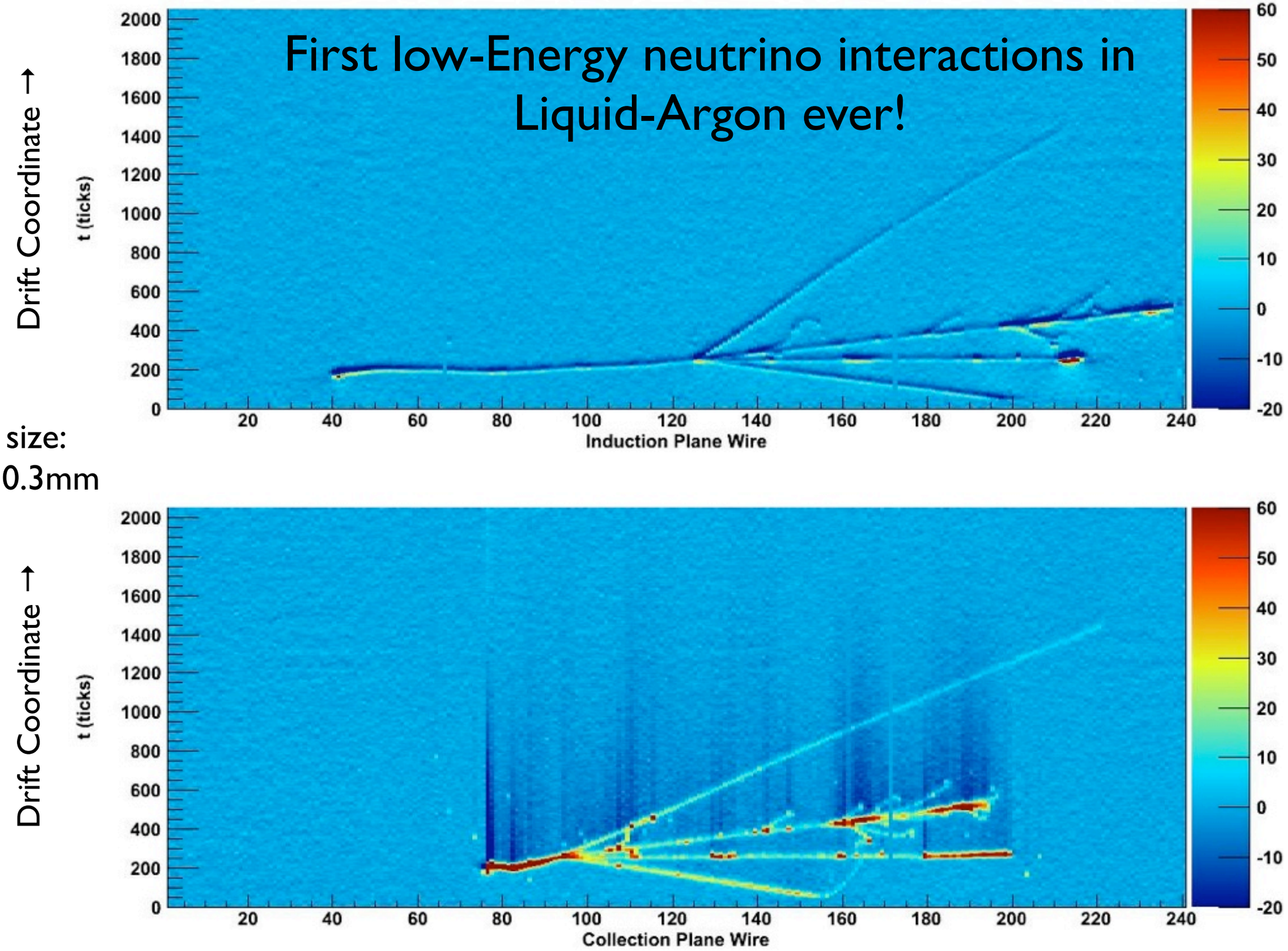
ArgoNeuT Neutrino Event

First low-Energy neutrino interactions in Liquid-Argon ever!

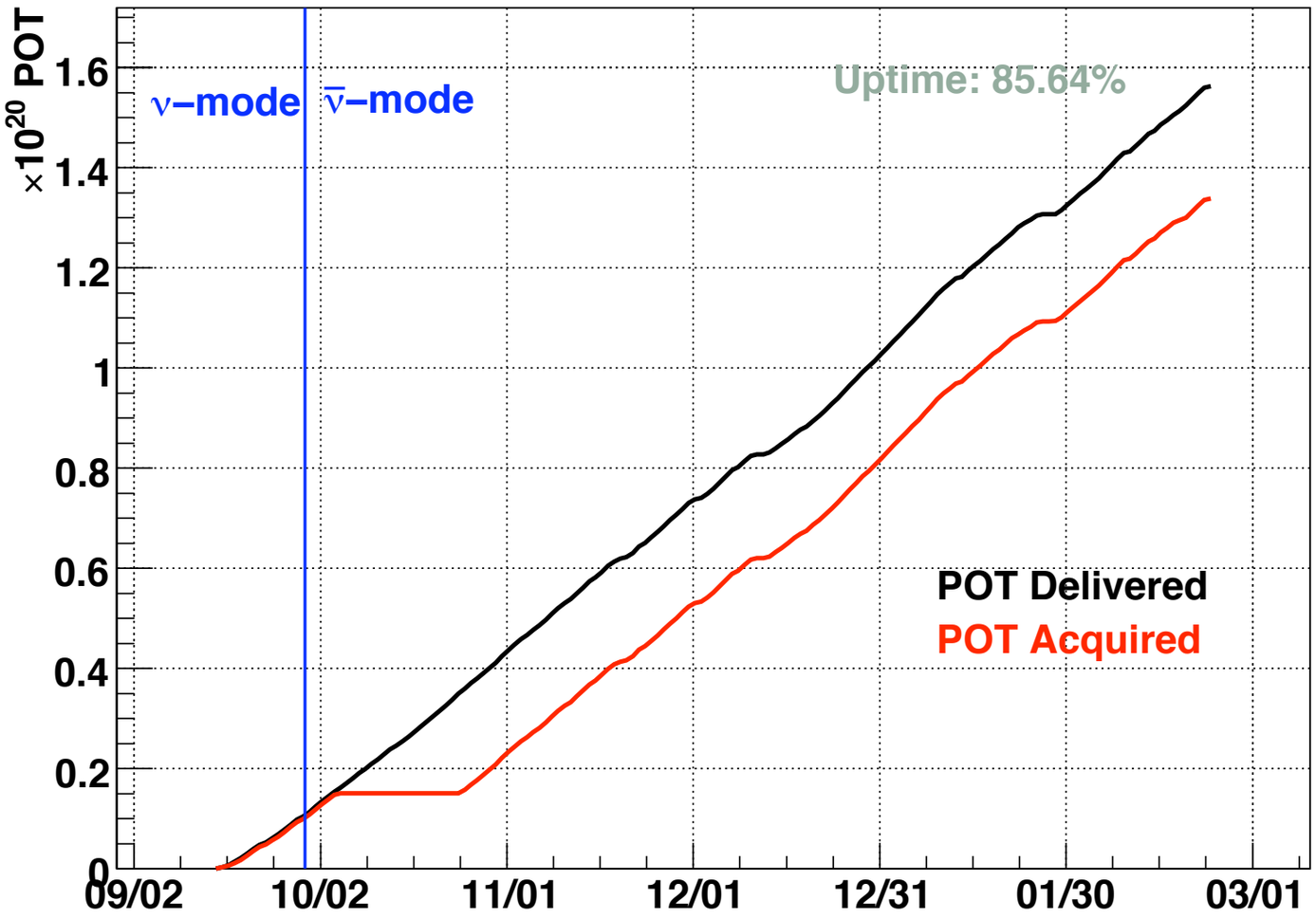
Pixel size:
4mm x 0.3mm



ArgoNeuT Physics

- ArgoNeuT acquired ~1.35E20 Protons On Target (P.O.T.) by the end of its run, mostly in anti-neutrino mode.
- This data is being used to develop techniques for reconstructing events in 3D.
- Proving particle identification capability (dE/dx) using data will be an important result.
- We should obtain several cross-section measurements for the first time in a LAr experiment!

ArgoNeuT POT delivered and accumulated



Event Type	# in 180 days (1.4×10^{20} POT)
ν_μ CC	28800
$\overline{\nu_\mu}$ CC	2520
ν_e CC	540
NC	9720

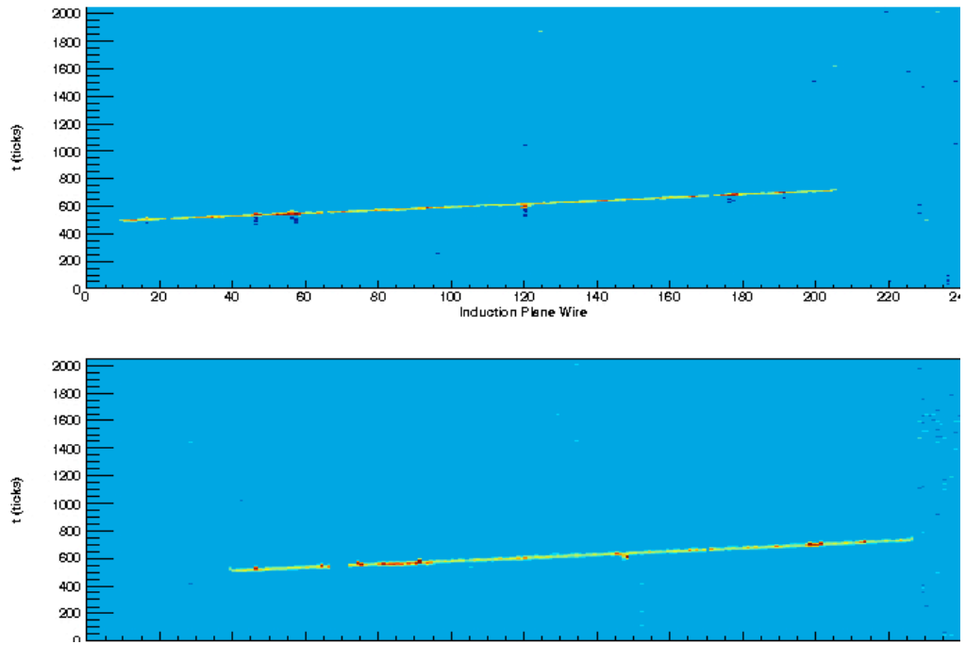
Neutrino Mode

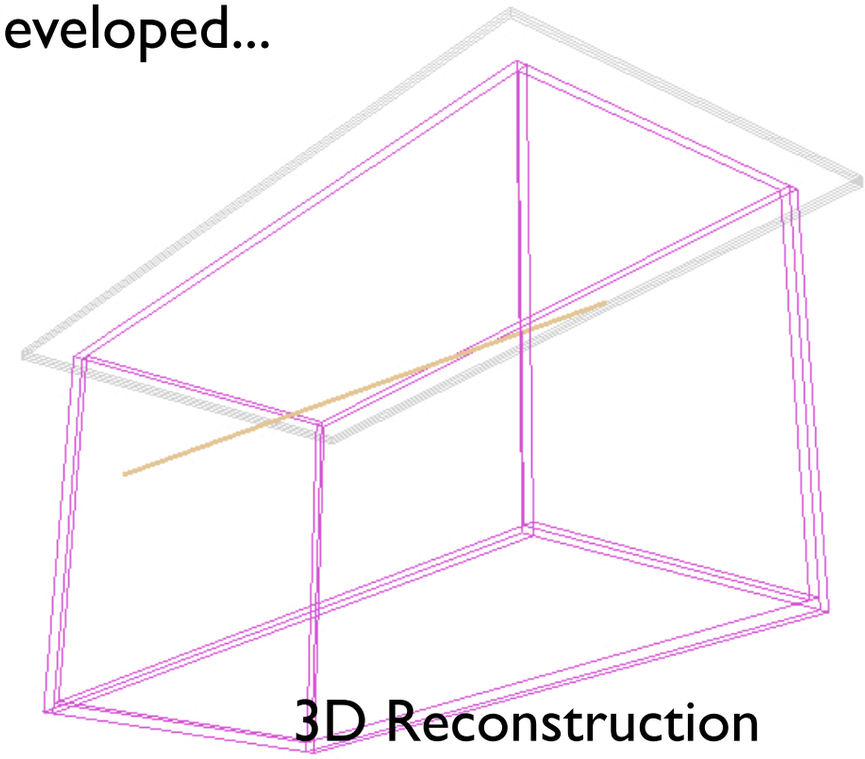
Event Type	# in 180 days (1.4×10^{20} POT)
ν_μ CC	9026
$\overline{\nu_\mu}$ CC	8111
ν_e CC	175
NC	5933

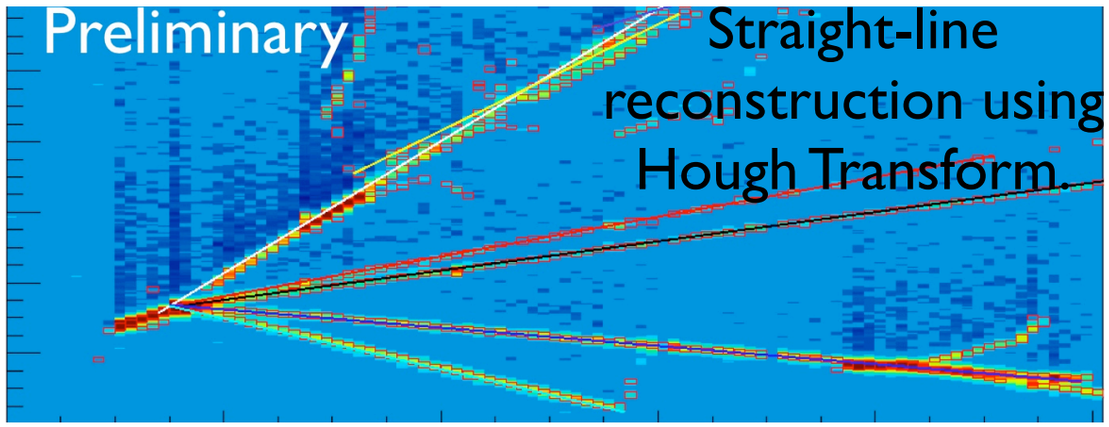
AntiNeutrino Mode

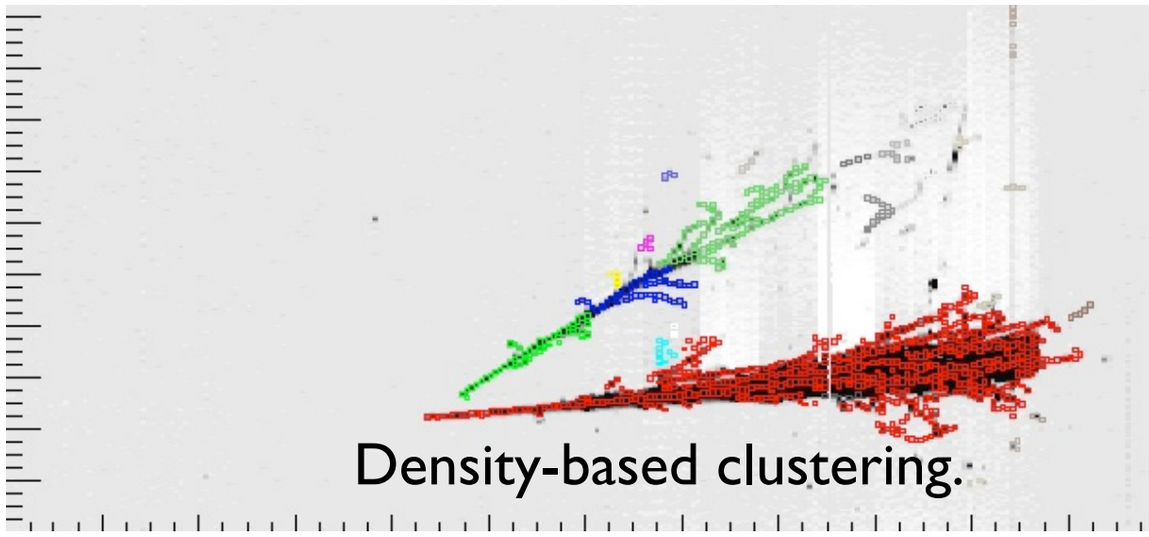
ArgoNeuT Software

- ArgoNeuT (anti)neutrino data spurring software/analysis work.
- We're creating our own LArTPC simulation/reconstruction software, nicknamed "LArSoft"
- LArSoft can/will be used for all future LAr experiments (MicroBooNE, LBNE, etc..).
- Example: Different reconstruction techniques being developed...




3D Reconstruction




Density-based clustering.

Conclusion

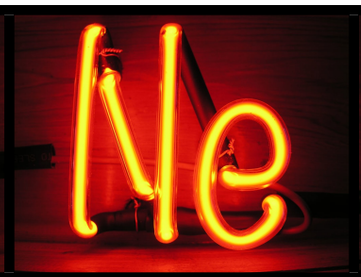
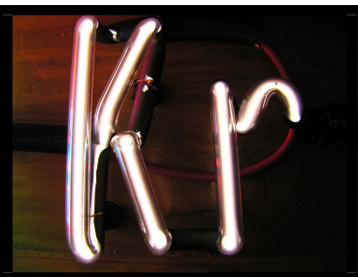
- ArgoNeuT run in the NuMI tunnel is now over…data analysis ramping up.
- Currently planning what to next with ArgoNeuT…stay tuned.

Thanks to everyone in Directorate, PPD, AD, ES&H, and CD who have helped make ArgoNeuT possible!

Back-Up Slides

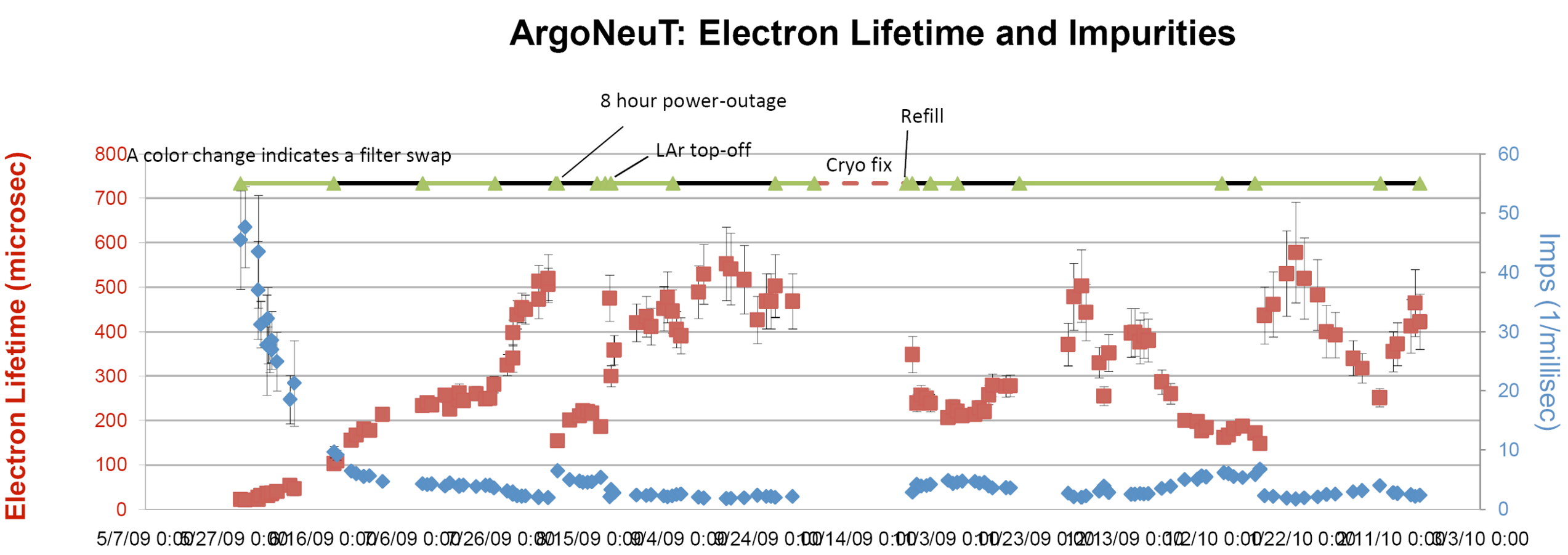
Why Noble Liquids for Neutrinos?

- Abundant ionization electrons and scintillation light can both be used for detection.
- If liquids are highly purified (<0.1ppb), ionization can be drifted over long distances.
- Excellent dielectric properties accommodate very large voltages.
- Liquids are dense, so they make a good target for neutrinos.
- **Argon** is relatively cheap and easy to obtain (1% of atmosphere).

						
Boiling Point [K] @ 1atm	4.2	27.1	87.3	120.0	165.0	373
Density [g/cm^3]	0.125	1.2	1.4	2.4	3.0	1
Radiation Length [cm]	755.2	24.0	14.0	4.9	2.8	36.1
dE/dx [MeV/cm]	0.24	1.4	2.1	3.0	3.8	1.9
Scintillation [γ /MeV]	19,000	30,000	40,000	25,000	42,000	
Scintillation λ [nm]	80	78	128	150	175	

Argon Purity

- Electron lifetime provides a measure of the purity of the liquid argon.
- We need a lifetime of several hundred microseconds in order to not lose an appreciable amount of charge as it drifts across the TPC.
- Plot below shows electron lifetime throughout the NuMI run.
- We learned a great deal about which cryogenic configurations gave the best purity improvements, and can use this information to achieve better performance in the future.



ArgoNeuT: Electronics

- Bias voltage distribution & blocking capacitors on the TPC
- FET preamplifier similar to D0/ICARUS front-end
- Wide bandwidth filtering (10 - 159 kHz, now)
  - Full information on most hits/tracks
  - Employ DSP to extract hit/track parameters
- Digitization boards (ADF2 from D0) sample at 5 MHz (198ns), 2048 samples/channel
- Minimize noise sources
  - Double shielding of feed-through and preamplifiers
  - Remote ducted cooling
  - Extensive DC power filtering